### I.2.11 HUMAN INTRUSION

Human intrusion was modeled based on a stylized scenario that is a conceptualization of the assumptions outlined in the Environmental Protection Agency standard (DIRS 157307-BSC 2001, Enclosure 1). The assumptions are based on recommendations of the National Research Council of the National Academy of Sciences. The Council observed that it is not possible to predict human behavior over the extremely long periods of concern and prescribed the scenario as a reasonable representation of typical inadvertent intrusion.

The models used were the same as those for the nominal scenario, except a source term was introduced for the time of the intrusion. This source term is characteristic of direct penetration of a waste package with a drill bit (DIRS 157307-BSC 2001, Enclosure 1).

### I.2.12 NUCLEAR CRITICALITY

A nuclear criticality occurs when sufficient quantities of fissionable materials come together in a precise manner and the required conditions exist to start and sustain a nuclear chain reaction. One of the required conditions is the presence of a moderator, such as water, in the waste package. The waste packages would be designed to make the probability of a criticality occurring inside the waste package extremely small. In addition, based on an analysis of anticipated repository conditions, it is very unlikely that a sufficient quantity of fissionable materials could accumulate outside the waste packages in the precise configuration and with the required conditions to create a criticality. If, somehow, an external criticality was to occur, analyses indicate that it would have only minor effects on repository performance. In the unlikely event that a criticality occurred, there would be a short-duration localized rise in temperature and pressure, as well as an insignificant increase in the repository radionuclide inventory. No measurable effect on repository performance would result from this event (DIRS 153849-DOE 2001, p. 4-416).

### I.2.13 ATMOSPHERIC RADIOLOGICAL CONSEQUENCES

In addition to the groundwater pathway, the analysis of long-term performance evaluated potential consequences of the release of radioactive gases into the environment. An analysis separate from the groundwater modeling described in the previous sections was used to forecast such consequences. The model used results from the waste package degradation models to evaluate when waste packages and fuel cladding would fail and, therefore, release contained radioactive gases. This model provided input to release and transport estimates for the atmospheric pathway. Section I.7 contains details of this analysis.

## I.3 Inventory

This section discusses the inventories of waterborne radioactive materials used to model radiological impacts and of some nonradioactive, chemically toxic waterborne materials used in the repository environment that could present health hazards. This section also discusses the inventory of atmospheric radioactive materials.

### I.3.1 INVENTORY FOR WATERBORNE RADIOACTIVE MATERIALS

There would be more than 200 radionuclides in the materials placed in the repository (see Appendix A of this EIS). In the Proposed Action, these radionuclides would be present in five basic waste forms: commercial spent nuclear fuel, mixed-oxide fuel and plutonium ceramic (called here *plutonium disposition waste*), borosilicate glass formed from liquid wastes on various DOE sites known as high-level radioactive waste, DOE-owned spent nuclear fuel, and naval spent nuclear fuel (DIRS 153246-CRWMS M&O 2000, Figure 3.5-4). In the repository, these wastes would be placed in several different types of waste packages of essentially the same construction but of varying sizes and with varying types of internal details. (DIRS 150558-CRWMS M&O 2000, Section 4.3). It is neither necessary nor practical to model the exact configuration of waste packages. The individual details of each package design are not significant parameters in modeling the processes involved in waste package degradation, waste form degradation, and radionuclide transport from the engineered barrier system. Constructing a TSPA model with each individual package and its unique design would result in a computer model too large to run on any available computer in a practical time. Therefore two representative types of waste packages were modeled in representative zones of the repository. The development of the two representative types of waste packages and their radionuclide inventories is the process of abstraction.

An abstracted inventory was used in the analysis of long-term groundwater impacts in much the same way as many other Features, Processes and Events were abstracted. The TSPA model is a high-level system model that performs hundreds of trials in a Monte Carlo framework. To make such a calculation tractable, it was necessary to reduce highly complex descriptions or behaviors to simplified concepts that capture the essential characteristics. In the case of inventory, the highly complex array of waste streams for the five fundamental waste categories (commercial spent nuclear fuel, plutonium-disposition waste, high-level radioactive waste, DOE-owned spent nuclear fuel, and naval spent nuclear fuel) were considered in developing the abstraction to representative waste packages that capture the essential features of the total inventory of radionuclide materials. The waste packages in the repository can be represented in two package types: a commercial spent nuclear fuel waste package and a codisposal waste package containing DOE spent nuclear fuel and high-level radioactive waste glass. The naval spent nuclear fuel was modeled as part of the commercial spent nuclear fuel. The plutonium disposition waste was split into the commercial spent nuclear fuel packages (mixed-oxide fuel) and codisposal package (immobilized plutonium within a high-level radioactive waste container) (DIRS 154841-BSC 2001, all).

The abstracted inventory has been carefully developed to maintain essential characteristics of the waste forms for the purpose of input to the TSPA model. As such, the TSPA abstracted inventory cannot be used for any other purpose, because it is not reality but rather a representation of reality that works only for the purpose intended. The averaging, blending, and screening of radionuclides to reduce the total number, while retaining essential physical characteristics of the waste, were all tailored to the TSPA model. Therefore, any attempt to compare this abstracted inventory with other abstractions used for other analyses in the repository will not be valid. The only essential comparison that can be made is that of the fundamental inputs to the abstraction process to fundamental inputs used in other analyses.

The abstraction of the inventory is shown in Figure I-2. In the figure, items in boxes are references to documents that either describe an analysis or are a data transmittal. The items not in boxes (next to the arrows) are the data produced from a documented analysis and used in another documented analysis.

Figure I-2 identifies four fundamental inputs:

- Input from DOE Environmental Management's National Spent Nuclear Fuel Program that identifies the characteristics of all DOE-owned spent nuclear fuel that would be sent to the repository (DIRS 110431-INEEL 1999, all)

- A body of high-level radioactive waste data collected from the EIS Data Call of 1997 (DIRS 104418-Rowland 1997); this includes information concerning high-level radioactive waste and plutonium-disposition waste

- A body of data that forms the database for commercial spent nuclear fuel; this is a collection of documents including key documents such as DOE/RW-0184 (DIRS 102588-DOE 1992, all) in its various revisions

- The *Monitored Geologic Repository Project Description Document* (DIRS 151853-CRWMS M&O 2000, all).

These four inputs were manipulated in various analyses that were brought together in the inventory abstraction (DIRS 157307-BSC, 2001, all) and are shown as the box at the bottom center of the figure. The fundamental data on commercial spent nuclear fuel was first processed in three analyses: simulation of a delivery schedule to the repository (DIRS 119348-CRWMS M&O 1999, all) (this was done using a standard computer code called CALVIN and source term studies for boiling-water reactor and pressurized-water reactor fuel that describe the typical radionuclide inventories for these spent fuels (DIRS 136428-CRWMS M&O 1999, all) (DIRS 136429-CRWMS M&O 1999, all). The CALVIN results are part of the input to the source term studies. All of the commercial spent nuclear fuel studies were then combined in a packaging study that describes the resulting spent nuclear fuel packages in the detailed design of the repository (DIRS 138239-CRWMS M&O 2000, all). The fundamental information on high-level radioactive waste was analyzed to determine decay and ingrowth of radionuclides in the waste and obtain inventory as a function of time (DIRS 147072-CRWMS M&O 1999, all). This study used the ORIGEN-S computer code, a standard code for determining inventories as a function of time. Fundamental data on DOE-owned spent nuclear fuel was analyzed to determine a packaging strategy (DIRS 149005-CRWMS M&O 2000, all). The results of this study identified three canister types and their inventories. At this point the results of commercial spent nuclear fuel, high-level radioactive waste, and DOE-owned spent nuclear fuel analyses were brought together in another analysis to develop a set of 13 standard package configurations (DIRS 153909-BSC 2001, all). This result was the basic set of detailed package configurations for the repository.

Another important analysis is the screening analysis. In this analysis, the contribution of specific radionuclides to inhalation and ingestion dose was determined and the radionuclides were ranked according to their contribution to total dose of all radionuclides (DIRS 153597-CRWMS M&O 2000, all). The metric for screening radionuclides is the radiation dose that a radionuclide could impose on a human living in the vicinity of Yucca Mountain. Identification of the important dose contributors is based on an estimate of the amount of radionuclides that could reach a human (DIRS 136383-CRWMS M&O 2000, all). Identification of the important dose contributors involves three steps:

1. For the waste form under consideration, the relative dose contribution from an individual radionuclide is calculated by multiplying its inventory abundance (in terms of its radioactivity) by its dose conversion factor (a number that converts an amount of a radionuclide into the dose that a human would incur if the radionuclide was ingested, inhaled, or came in close proximity). This multiplication gives a result that can be compared to values derived in the same manner for other radionuclides to determine the more important contributors to the dose.

2. The individual radionuclides are ranked, with the highest contributor to the dose given the highest ranking, and the percent contribution of each radionuclide in the list to the total dose (the sum of the doses from the radionuclides in the list) is calculated.

3. Radionuclides that are included in the analysis are the highest-ranked radionuclides that, when their dose contributions are combined, produce 95 percent of the dose.

These steps identify which radionuclides would be included in the dose estimate, if all the radionuclides in a waste form were released to the environment in proportion to their inventory abundance. However, radionuclides are not always released in proportion to their inventory abundance. Factors that can affect releases of radionuclides, depending on the scenario being considered, include radionuclide longevity, solubility, and transport affinity.

Radionuclide longevity is the lifetime of a radionuclide before it decays. Solubility is the amount of a radionuclide that will dissolve in a given amount of water. Transport affinity is a radionuclide's potential for movement through the environment. This movement can involve a number of mechanisms, for example: fracture flow (the movement of radionuclides with water flowing in fractures), matrix diffusion (the diffusion of radionuclides from water in the fractures into water in the matrix), or colloidal-facilitated transport (the movement of radionuclides associated with small particles of rock or waste form degradation products). Transport affinity is not a measurable property, but a qualitative description of the likelihood of transport. If a group of radionuclides is transported via a particular mechanism, and that mechanism dominates release, the group of radionuclides will be preferentially released (relative to radionuclides not in the group) to the environment. If a radionuclide has a short half-life, it will have a higher activity in the waste form at early times (close to repository closure); however, at later times, the radionuclide will have all but disappeared from the waste form. If a radionuclide is not soluble in the near-field environment around the waste package, it may not be released to the environment through groundwater transport, even if it is abundant and available.

Because radionuclide longevity, solubility, and transport affinity can affect releases of radionuclides, the identification of important dose contributors includes examination of possible "what-if" scenarios that could result in releases of radionuclides to the environment. For example, "What if radionuclide releases are the result of a colloidal transport mechanism? If the steps described above are applied to the subset of radionuclides that could be released through a colloidal-transport mechanism (radionuclides that readily bind to rock and colloidal particles), which of those radionuclides would be identified as the important contributors to dose?" Or, "What if a volcanic direct release to the environment occurs? If the steps described above are applied to the radionuclides present in the waste form in a direct release, which of those radionuclides would be identified as the important contributors to dose?" The radionuclide screening examined over 1,200 potential what-if scenarios and identified the important dose contributors for each one. The cases examined consider times from 100 to 1 million years after repository closure (100, 200, 300, 400, 500, 1,000, 2,000, 5,000, 10,000, 100,000, 300,000, and 1,000,000 years); eight waste forms (average and bounding pressurized-water reactor fuel, average and bounding boiling-water reactor fuel, average and bounding DOE spent nuclear fuel, and average and bounding DOE high-level radioactive waste); three transport affinity groups (highly sorbing, moderately sorbing, and slightly to nonsorbing); and two exposure pathways (inhalation and ingestion).

In addition to the radionuclides selected based on contribution to dose, other radionuclides (in particular radium-226 and radium-228) must be considered because of the groundwater protection requirements in 40 CFR Part 197. Other radionuclides must also be considered in the analysis because they belong to decay chains; they must be included to accurately track other members of the decay chains. (A decay chain is a sequence of radionuclides that, because of radioactive decay, change from one to the other; thus, the amount of one is dependent on the amounts of the others.)

The complete list of radionuclides produced by the screening merges all the lists of radionuclides developed from the various scenarios. For example, if a radionuclide is important for estimating the dose from DOE spent nuclear fuel, it is included in the analysis even though these waste forms would occupy a small fraction of the repository. Similarly, if a radionuclide is important for estimating the dose from the highly sorbing transport group, it is included in the analysis, even if analyses show that colloid transport is a minimal contributor to release.

The inventory abstraction then took as input the 13 configurations, the design of the repository, the screening analysis, and a special americium-241 ingrowth analysis (DIRS 153596-CRWMS M&O 2001, all). The abstraction provided two fundamental results:

- The total initial inventory for the TSPA model for the Proposed Action represented as the quantity of radionuclides in two representative waste package types. The total number of radionuclides represented has been reduced by a screening process with two criteria: elimination of all radionuclides with a half-life less than 20 years and inclusion of all radionuclides that contribute at least 95 percent of the total radiological dose.

- A recommended list of radionuclides to track for each of three scenarios: nominal scenario, disruptive events (volcanism) scenario, and human intrusion scenario. Not all radionuclides in the master list are necessarily included in a particular scenario. This is because some radionuclides are not important in some scenarios.

Additional analyses for this EIS included consideration of two other inventories that are not part of the Proposed Action. These analyses supported the analysis of cumulative impacts from possible future actions. The first of these is the addition of more commercial spent nuclear fuel. The combined inventory of the Proposed Action and this additional commercial spent nuclear fuel is referred to as Inventory Module 1. In addition, a category for Greater-Than-Class-C plus Special-Performance-Assessment-Required materials (Inventory Module 2 only) could be added in the future. The waste packages in this calculation include the commercial spent nuclear fuel packages and DOE spent nuclear fuel and high-level radioactive waste codisposal packages described in DIRS 150558-CRWMS M&O (2000, all). This EIS assumes that the Inventory Module 2 Greater-Than-Class-C and Special-Performance-Assessment-Required waste would be packaged in codisposal waste packages (DIRS 155393-CRWMS M&O 2000, Attachment II). The numbers of idealized waste packages used in the calculations are listed in Table I-4.

**Table I-4.** Modeled number of idealized waste packages by category type for the abstracted inventories of the Proposed Action, Inventory Module 1, and Inventory Module 2.

| Waste category | Proposed Action | Inventory Module 1 | Inventory Module 2 |
|---|---|---|---|
| Commercial spent nuclear fuel[a] | 7,860 | 11,754 | 0[b] |
| DOE spent nuclear fuel/high-level radioactive waste codisposal | 3,910 | 4,877 | 0[b] |
| Greater-Than-Class-C | 0 | 0 | 201 |
| Special-Performance-Assessment-Required | 0 | 0 | 400 |
| ***Total*** | ***11,770*** | ***16,631*** | ***601***[b] |

a. 300 U.S. Navy spent nuclear fuel waste packages are modeled as commercial spent nuclear fuel waste packages.
b. Inventory Module 2 would include all packages in Inventory Module 1 plus the numbers shown for Greater-Than-Class-C and Special-Performance-Assessment Required waste packages; however, for modeling purposes only the *incremental increase* in the number of waste packages was modeled and the result added to the result for Inventory Module 1 impacts to estimate Inventory Module 2 impacts.

The physical properties of the various waste forms to be placed in the proposed Yucca Mountain repository are described in detail in DIRS 151109-CRWMS M&O (2000, all).

### I.3.1.1 Radionuclide Inventory Used in the Model of Long-Term Performance for Proposed Action

The tabulated per-waste-package inventory used in the Proposed Action calculations is listed in Table I-5.

### I.3.1.2 Radionuclide Inventory Used in the Model of Long-Term Performance for Inventory Module 1

The abstracted per-waste-package radionuclide inventory used for the Proposed Action also applies to additional waste packages for the expansion of the repository to include all potential commercial and DOE waste under Inventory Module 1. In other words, the number of packages is increased for Inventory Module 1 compared to the Proposed Action, but the content of each individual idealized waste package remains the same.

**Table I-5.** Abstracted inventory (grams) of radionuclides passing the screening analysis in each idealized waste package for commercial spent nuclear fuel, DOE spent nuclear fuel, and high-level radioactive waste for Proposed Action, Inventory Module 1, and Inventory Module 2.[a,b]

| Radionuclide | Commercial spent nuclear fuel waste packages | Codisposal waste packages | |
|---|---|---|---|
| | | DOE spent nuclear fuel | High-level radioactive waste |
| Actinium-227 | 0.00000309 | 0.000113 | 0.000467 |
| Americium-241 | 10,900 | 117 | 65.7 |
| Americium-243 | 1,290 | 1.49 | 0.399 |
| Carbon-14 | 1.37 | 0.0496 | 0.00643 |
| Cesium-137 | 5,340 | 112 | 451 |
| Iodine-129 | 1,800 | 25.1 | 48 |
| Neptunium-237 | 4,740 | 47.9 | 72.3 |
| Proactinium-231 | 0.00987 | 0.325 | 0.796 |
| Lead-210 | 0 | 0.000000014 | 0.000000114 |
| Plutonium-238 | 1,510 | 6.33 | 93.3 |
| Plutonium-239 | 43,800 | 2,300 | 3,890 |
| Plutonium-240 | 20,900 | 489 | 381 |
| Plutonium-242 | 5,410 | 11.1 | 7.77 |
| Radium-226 | 0 | 0.00000187 | 0.0000167 |
| Radium-228 | 0 | 0.00000698 | 0.00000319 |
| Strontium-90 | 2,240 | 55.4 | 288 |
| Technetium-99 | 7,680 | 115 | 729 |
| Thorium-229 | 0 | 0.0266 | 0.00408 |
| Thorium-230 | 0.184 | 0.0106 | 0.00782 |
| Thorium-232 | 0 | 14,900 | 7,310 |
| Uranium-232 | 0.0101 | 0.147 | 0.000823 |
| Uranium-233 | 0.07 | 214 | 11.1 |
| Uranium-234 | 1,830 | 57.2 | 47.2 |
| Uranium-235 | 62,800 | 8,310 | 1,700 |
| Uranium-236 | 39,200 | 853 | 39.8 |
| Uranium-238 | 7,920,000 | 509,000 | 261,000 |

a. Source: DIRS 154841-BSC (2001, Table 36, p. 38).
b. The idealized waste packages in the simulation (model) are based on the inventory abstraction. While the total inventory is represented by the material in the idealized waste packages, the actual number of waste packages emplaced in the potential repository would be different. The numbers of idealized waste packages modeled for various inventory abstractions are listed in Table I-4.

### I.3.1.3 Radionuclide Inventory Used in the Model of Long-Term Performance for Inventory Module 2

Wastes with concentrations above Class-C limits (shown in 10 CFR 61.55, Tables 1 and 2) for long and short half-life radionuclides, respectively, are called Greater-Than-Class-C low-level waste. These wastes generally are not suitable for near-surface disposal. The Greater-Than-Class-C waste inventory is discussed in detail in Appendix A, Section A.2.5, of this EIS.

DOE Special-Performance-Assessment-Required low-level radioactive waste could include production reactor operating wastes, production and research reactor decommissioning wastes, non-fuel-bearing components of naval reactors, sealed radioisotope sources that exceed Class-C limits for waste classification, DOE isotope production related wastes, and research reactor fuel assembly hardware. The Special-Performance-Assessment-Required waste inventory is discussed in detail in Appendix A.

The final disposition method for Greater-Than-Class-C and Special-Performance-Assessment-Required low-level radioactive waste is not known. If these wastes were to be placed in a repository, they would be placed in canisters before shipment. This appendix assumes the use of a canister similar to the naval dual-purpose canister described in Section A.2.2.5.6 of Appendix A of this EIS.

**IDEALIZED WASTE PACKAGES**

The number of waste packages used in the performance assessment simulations do not exactly match the number of waste packages projected for the Proposed Action.

The TSPA model uses two types of *idealized waste packages* (commercial spent nuclear fuel package and co-disposal package), representing the averaged inventory of all the actual waste packages used for a particular waste category.

While the number of idealized waste packages varies from the number of actual waste packages, the total radionuclide inventory represented by all of the idealized waste packages collectively is representative of the total inventory, for the radionuclides analyzed, given in Appendix A of this EIS for the purposes of analysis of long-term performance. The abstracted inventory is designed to be representative for purposes of analysis of long-term performance and cannot necessarily be used for any other analysis, nor can it be directly compared to any other abstracted inventory used for other analyses in this EIS.

Table I-6 lists existing and projected volumes through 2055 for the three Greater-Than-Class-C waste sources. DOE conservatively assumes 2055 because that year would include all Greater-Than-Class-C low-level waste resulting from the decontamination and decommissioning of commercial nuclear reactors. The projected volumes conservatively reflect the highest potential volume and activity expected based on inventories, surveys, and industry production rates.

The data concerning the volumes and projections of Greater-Than-Class-C low-level waste are from Appendix A-1 of the *Greater-Than-Class-C Low-Level Radioactive Waste Characterization: Estimated Volumes, Radionuclide Activities, and Other Characteristics* (DIRS 101798-DOE 1994, all). That appendix provides detailed radioactivity reports for such waste currently stored at nuclear utilities.

The only difference between Inventory Modules 1 and 2 is the addition of Greater-Than-Class-C and Special-Performance-Assessment-Required wastes under Inventory Module 2. This represents an incremental increase in the total inventory for Inventory Module 2 over Inventory Module 1, with no difference in the temperature operating mode or the areal extent of the repository disposal area. Because of this, calculations for analysis of long-term performance for Inventory Module 2 were performed considering only Greater-Than-Class-C and Special-Performance-Assessment-Required waste inventories, and the results treated as an incremental increase to the impacts predicted for analysis of long-term performance of Inventory Module 1.

**Table I-6.** Greater-Than-Class-C low-level waste volumes (cubic meters)[a] by source.[b]

| Source | 1993 | 2055 |
|---|---|---|
| Nuclear electric utility | 26 | 1,300 |
| Sealed sources | 39 | 240 |
| Other | 74 | 470 |
| ***Totals*** | ***139*** | ***2,010*** |

a. To convert cubic meters to cubic feet, multiply by 35.314.
b. Source: DIRS 101798-DOE (1994, Tables 6-1 and 6-3).

The radionuclide inventory used for Inventory Module 2 (Greater-Than-Class-C and Special-Performance-Assessment-Required materials) is described and tabulated in Appendix A of this EIS and the abstracted per-package inventory developed from these data is listed on Table I-7. The details of

**Table I-7.** Abstracted inventory (grams) of radionuclides passing the screening analysis in each idealized waste package for Greater-Than-Class-C and Special-Performance-Assessment-Required waste (grams per waste package) under Inventory Module 2.[a,b]

| Radionuclide | Greater-Than-Class-C and Special-Performance-Assessment-Required | Radionuclide | Greater-Than-Class-C and Special-Performance-Assessment-Required |
|---|---|---|---|
| Actinium-227 | 0 | Plutonium-242 | 0.00614 |
| Americium-241 | 40 | Radium-226 | 0.0504 |
| Americium-243 | 0.00151 | Strontium-90 | 0.82 |
| Carbon-14 | 28.9 | Technetium-99 | 568 |
| Cesium-137 | 771 | Thorium-229 | 0 |
| Iodine-129 | 0.000705 | Thorium-230 | 0 |
| Neptunium-237 | 0 | Uranium-232 | 0.00000287 |
| Protactinium-231 | 0 | Uranium-233 | 0.00419 |
| Lead-210 | 0 | Uranium-234 | 0 |
| Plutonium-238 | 1.56 | Uranium-235 | 0 |
| Plutonium-239 | 2,860 | Uranium-236 | 0 |
| Plutonium-240 | 0.0123 | Uranium-238 | 563,000 |
| Plutonium-241 | 0.0207 | | |

a. Source: DIRS 157307-BSC (2001, Enclosure 1).
b. The idealized waste packages in the simulation (model) are based on the inventory abstraction. While the total inventory is represented by the material in the idealized waste packages, the actual number of waste packages emplaced in the potential repository would be different.

obtaining the per-package inventory for Greater-Than-Class-C and Special-Performance-Assessment-Required materials are described in DIRS 157307-BSC (2001, Attachment III).

### I.3.2 INVENTORY FOR WATERBORNE CHEMICALLY TOXIC MATERIALS

Waterborne chemically toxic materials that present a potential human health risk would be present in materials disposed of in the repository. The most abundant of these materials would be nickel, chromium, and molybdenum (which would be used in the waste package) and uranium (in the disposed waste). Uranium is both a chemically toxic and a radiological material. Screening studies were conducted to determine if any of these or other materials would be released in sufficient quantities to have a meaningful impact on groundwater quality.

An inventory of chemical materials to be placed in the repository under the Proposed Action was prepared. The inventories of the chemical components in the repository were combined into four groups:

- Materials not part of engineered barrier system
- Components of the engineered barrier system including:
  - Titanium drip shields
  - Alloy-22 in the outer layer of the waste packages
  - Stainless steel in the inner layer of the waste packages
- Other materials internal to the waste packages
- High-level radioactive waste

These materials were organized into groups with similar release times for use in the screening study. Table I-8 lists the chemical inventories. Plutonium is not listed in Table I-8 because, while it is a heavy metal and therefore could have toxic effects, its radiological toxicity far exceeds its chemical toxicity (DIRS 102205-DOE 1998, Section 2.6.1). In addition, while there are radiological limits set for exposure

**Table I-8.** Inventory (kilograms)[a] of chemical materials placed in the Proposed Action repository.

| | Inventory | | | | |
|---|---|---|---|---|---|
| Element | Not part of engineered barrier system | Engineered barrier system components exposed before waste package failure | Internal to waste package including inner sleeve | High-level radioactive waste[b] | Totals |
| Aluminum | 0 | 0 | 2,452,400 | 0 | 2,452,400 |
| Barium | 0 | 0 | 50,000 | 74,000[c] | 124,000 |
| Boron | 0 | 0 | 197,400 | 0 | 197,400 |
| Cadmium | 0 | 0 | 3,400 | 43,000 | 46,400 |
| Carbon | 318,738 | 547 | 5,000 | 0 | 324,285 |
| Chromium | 0 | 23,735,000 | 26,414,000 | 0 | 50,149,000 |
| Cobalt | 0 | 0 | 27,000 | 0 | 27,000 |
| Copper | 243,800 | 0 | 3,000 | 0 | 246,800 |
| Iron | 111,916,880 | 1,190,000 | 161,695,000 | 0 | 274,801,880 |
| Lead | 0 | 0 | 0 | 2,000 | 2,000 |
| Magnesium | 0 | 0 | 12,000 | 0 | 12,000 |
| Manganese | 1,189,576 | 575,880 | 3,732,100 | 0 | 5,497,556 |
| Mercury | 0 | 0 | 0 | 200 | 200 |
| Molybdenum | 0 | 17,307,000 | 3,839,100 | 0 | 21,146,100 |
| Nickel | 0 | 60,797,000 | 18,659,100 | 0 | 79,456,100 |
| Phosphorus | 39,842 | 820 | 91,200 | 0 | 131,862 |
| Selenium | 0 | 0 | 0 | 300 | 300 |
| Silicon | 330,122 | 18,226 | 1,680,500 | 0 | 2,028,848 |
| Sulfur | 39,842 | 547 | 68,200 | 0 | 108,589 |
| Titanium | 0 | 4,148,000 | 2,000 | 0 | 4,150,000 |
| Uranium | 0 | 0 | 70,000,000 | 0 | 70,000,000 |
| Vanadium | 0 | 377,600 | 0 | 0 | 377,600 |
| Zinc | 0 | 0 | 3,000 | 0 | 3,000 |

a. To convert kilograms to pounds, multiply by 2.2046

b. The high-level radioactive waste form to be placed in the potential repository would not exhibit the Characteristic of Toxicity as measured by the Toxicity Characteristic Leaching Procedure (40 CFR 261.24).

c. Includes barium grown in from decay of all of the cesium.

to plutonium, no chemical toxicity benchmarks have been developed for this element. Therefore, lacking data to analyze chemical toxicity, plutonium was not analyzed for the chemical screening.

### I.3.3 INVENTORY FOR ATMOSPHERIC RADIOACTIVE MATERIALS

The only radionuclide that would have a relatively large inventory and a potential for gas transport would be carbon-14. Iodine-129 can exist in a gas phase, but it is highly soluble and therefore likely to dissolve in groundwater rather than migrate as a gas. Radon-222 is a gas, but would decay to a solid isotope before escaping from the repository region (see Section I.7.3). After carbon-14 escaped from the waste package, it could flow through the rock in the form of carbon dioxide. About 2 percent of the carbon-14 in commercial spent nuclear fuel occurs in a gas phase in the space (or *gap*) between the fuel and the cladding around the fuel (DIRS 103446-Oversby 1987, p. 92). The gas-phase inventory consists of 0.122 curie of carbon-14 per commercial spent nuclear fuel waste package. Table I-9 lists the carbon-14 inventory for commercial spent nuclear fuel under the Proposed Action and Inventory Modules 1 and 2.

## I.4 Extension of TSPA Methods and Models for EIS Analysis of Long-Term Performance

The TSPA model nominal scenario is equivalent to the Proposed Action inventory for an individual at the RMEI location [approximately 18 kilometers (11 miles) downgradient from the proposed repository]. Details on the adaptations, extensions, and modifications to the software and models used for the TSPA